# THEORETICAL MAXIMUM SPECIFIC GRAVITY AND DENSITY OF HOT MIX ASPHALT PAVING MIXTURES
# FOP FOR AASHTO T 209

## Significance

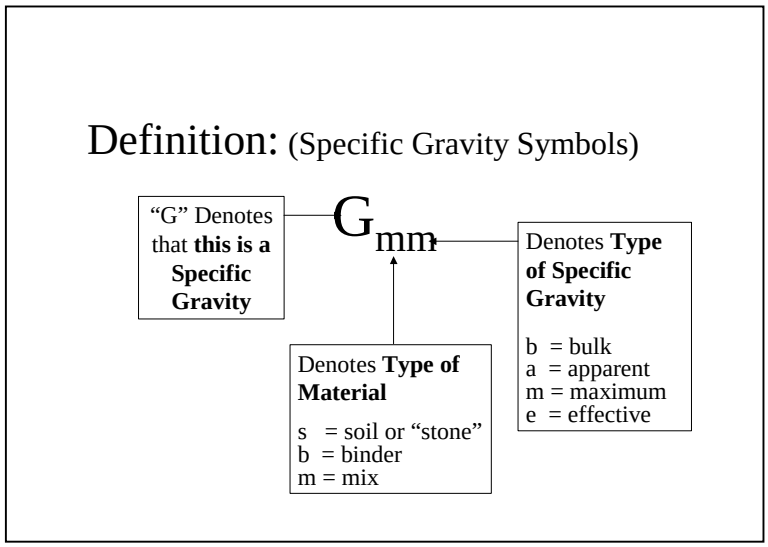
01 Maximum specific gravity ($G_{mm}$) is the ratio of the mass of a given volume of cooled hot mix asphalt (HMA) at 25°C (77°F) to the mass of an equal volume of water at the same temperature. The procedure is often called the Rice test after its developer, James Rice. $G_{mm}$ is used in conjunction with bulk specific gravity to determine in-place

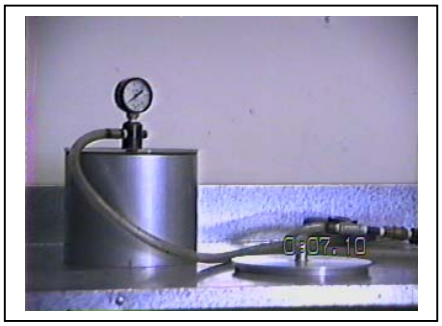
02 density and / or percent air voids in compacted HMA. Percentage of air voids, $V_a$, is significant because durability characteristics of HMA are influenced by the amount of voids in the compacted material.

## Scope

04 This procedure covers the determination of the maximum specific gravity ($G_{mm}$) of uncompacted Hot Mix Asphalt (HMA) paving mixtures in accordance with AASHTO T 209. Two methods using two different containers – bowl and flask – are covered.

03 Specimens prepared in the laboratory shall be cured according to the agency standard.





**Metal container/ Volumetric Flask**

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## Apparatus

- Balance or scale: 10,000 g capacity, readable to 0.1 g
- Container: A glass, metal, or plastic bowl or volumetric flask capable of holding a 2000 g sample and withstanding a partial vacuum
- Container cover: A glass plate or a metal or plastic cover with a vented opening.

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- Vacuum Lid: A transparent lid with a suitable vacuum connection. The vacuum opening to be covered with a fine wire mesh
- Vacuum pump or water aspirator: Capable of evacuating air from the container to a residual pressure of 4.0 kPa (30 mm Hg).
- Manometer or Vacuum gauge: Traceable to NIST and capable of measuring residual pressure down to 4.0 kPa (30 mm Hg) or less.
- Water bath: A constant-temperature water bath (optional)
- Thermometers: Calibrated liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (0.9°F)
- Bleeder valve to adjust vacuum.
- Timer

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## Calibration of Flask

Use a volumetric flask that is calibrated to accurately determine the mass of water, at 25 ±0.5°C (77 ±0.9°F), in the flask. The volumetric flask shall be calibrated periodically in conformance with procedures established by the agency.

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## Test Sample Preparation

1. Obtain samples in accordance with the FOP for AASHTO T 168 and reduce according to the FOP for WAQTC TM 5.
2. Test sample size shall conform to the requirements of Table 1. Samples larger than the capacity of the container may be tested in two or more increments. Results will be combined and averaged. If the increments have a specific gravity difference greater than 0.018 for the bowl

method and 0.011 for the flask method the test must be re-run.

**Table 1**
**Test Sample Size for $G_{mm}$**

| Size of Largest Particle of Aggregate in Mixture mm (in.) | Minimum Mass g |
|---|---|
| 50.0 (2) | 6000 |
| 37.5 (1 ½) | 4000 |
| 25 (1) | 2500 |
| 19 (3/4) | 2000 |
| 12.5 (1/2) | 1500 |
| 9.5 (3/8) | 1000 |
| 4.75 (No. 4) | 500 |

**Separating particles**

**Placing sample in flask**

## Procedure – General

Two procedures – bowl and flask – are covered. The first 11 steps are the same for both.

1. Separate the particles of the sample, taking care not to fracture the mineral particles, so that the particles of the fine aggregate portion are not larger than 6.3 mm (1/4 in.). If the mixture is not sufficiently soft to be separated manually, place it in a large flat pan and warm in an oven only until it is pliable enough for separation.
2. Cool the sample to room temperature.
3. Determine and record the mass of the dry bowl or flask, including the cover, to the nearest 0.1 g.
4. Place the sample in the bowl or flask.
5. Determine and record the mass of the dry bowl or flask, cover, and sample to the nearest 0.1 g.
6. Determine and record the mass of the sample by subtracting the mass determined in Step 3 from the mass determined in Step 5. Designate this mass as “A”.
7. Add sufficient water at approximately 25° ±1°C

(77° ±1.8°F) to cover the sample by about 25 mm (1 in).

***Note 1:*** The release of entrapped air may be facilitated by the addition of a wetting agent. Check with the agency to see if this is permitted and, if it is, for a recommended agent.

8. Place the lid on the bowl or flask and attach the vacuum line. To ensure a proper seal between the flask and the lid, wet the O-ring or use a petroleum gel.

9. Remove entrapped air by subjecting the contents to a partial vacuum of 3.7 ±0.3 kPa (27.5 ±2.5 mm Hg) residual pressure for 15 ±2 minutes.

10. Agitate the container and contents, either continuously by mechanical device or manually by vigorous shaking, at 2-minute intervals. This agitation facilitates the removal of air.

11. Slowly open the release valve, turn off the vacuum pump and remove the lid.

## Procedure – Bowl

12A. Suspend and immerse the bowl and contents in water at 25 ±1.0°C (77 ±1.8°F) for 10 ±1 minutes. The holder shall be immersed sufficiently to cover it and the bowl.

13A. Determine and record the submerged weight of the bowl and contents to the nearest 0.1 g.

14A. Empty and re-submerge the bowl following step 12A to determine the submerged weight of the bowl to the nearest 0.1 g.

15A. Determine and record the submerged weight of the sample the nearest 0.1 g by subtracting the submerged weight of the bowl from the submerged weight determined in Step 13A. Designate this submerged weight as “C”.

**Determining mass**

## Procedure – Flask

22 12B. Fill the flask with water, place in a 25 ±1°C (77 ±1.8°F) water bath and allow to stand for 10 ±1 minutes.

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***Note 2:*** In lieu of placing the flask in the water bath, after standing 10 minutes determine the temperature of the water in the flask and make the appropriate density correction using Table 2.

13B. Finish filling the flask, place the metal or plastic cover or a glass plate on the flask, and eliminate all air from the flask.

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***Note 3***: When using the metal flask and cover, place the cover on the flask and push down slowly, forcing excess water out of the hole in the center of the cover. Use care when filling flask to avoid reintroducing air into the water.

25 14B. Wipe off excess water from the flask and cover.

15B. Determine and record the mass of the flask, cover, de-aired water, and sample to the nearest 0.1 g. Designate this mass as "E".

16B Mass "D", the mass of the flask and water, is determined during the Calibration of Flask procedure.

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## Procedure – Mixtures Containing Uncoated Porous Aggregate

27 If the pores of the aggregates are not thoroughly sealed by a bituminous film, they may become saturated with water during the vacuuming procedure, resulting in an error in maximum density.

To determine if this has occurred, complete the general procedure and then:

1. Drain water from sample through a towel held over top of container to prevent loss of material.
2. Spread sample before an electric fan to remove surface moisture.

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3. Determine the mass of the sample when the surface moisture appears to be gone.
4. Continue drying and determine the mass of the sample at 15-minute intervals until less than a 0.5 g loss is found between determinations.

5. Record the mass as the saturated surface-dry mass to the nearest 0.1 g. Designate this mass as "$A_{SSD}$".
6. Calculate, as indicated below, $G_{mm}$ using "A" and "$A_{SSD}$", and compare the two values.

## Calculation

Calculate the $G_{mm}$ to three decimal places as follows.

**Bowl Procedure**



$$G_{mm} = \frac{A}{A - C}$$

where:

A = mass of dry sample in air, g

C = submerged weight of sample in water, g

Example:

A = 1432.7 g

C = 848.6 g

$$G_{mm} = \frac{1432.7\,g}{1432.7\,g - 848.6\,g} = 2.453$$

**Flask Procedure**

$$G_{mm} = \frac{A}{A + D - E} \times R$$

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or

$$G_{mm} = \frac{A}{A_{SSD} + D - E} \times R$$

(for mixtures containing uncoated aggregate materials)

where:

A = Mass of dry sample in air, g

$A_{SSD}$ = Mass of saturated surface-dry sample in air, g

D = Mass of flask filled with water at 25°C (77°F), g

E = Mass of flask filled with water and the test sample at test temperature, g

R = Factor from Table 2 to correct the density of water – used only if a test temperature other than 25°C (77°F) is used

Example (in which two increments are averaged):

| Test 1 | Test 2 |
|---|---|
| A = 1200.3 g | A = 960.2 g |
| D = 7502.5 g | D = 7525.5 g |
| E = 8217.1 g | E = 8096.3 g |
| Temperature = 26.2°C | Temperature = 25.0°C |

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$$G_{mm_1} = \frac{1200.3\ \text{g}}{1200.3\ \text{g} + 7502.5\ \text{g} - 8217.1\ \text{g}} \times 0.99968 = 2.470$$

$$G_{mm_2} = \frac{960.2\,\text{g}}{960.2\,\text{g} + 7525.5\,\text{g} - 8096.3\,\text{g}} \times 1.00000 = 2.466$$

2.470-2.466= 0.004, which is < 0.011 so they can be averaged.

Average

2.470-2.466= 0.004 0.004÷ 2= 0.002 0.002+2.466= **2.468**

**Table 2**
**Temperature Correction Factor**

| °C | °F | "R" | | °C | °F | "R" |
|---|---|---|---|---|---|---|
| 20.0 | 68.0 | 1.00117 | | 23.3 | 74.9 | 1.00042 |
| 20.1 | 68.2 | 1.00114 | | 23.4 | 74.1 | 1.00040 |
| 20.2 | 68.4 | 1.00112 | | 23.5 | 74.3 | 1.00037 |
| 20.3 | 68.5 | 1.00110 | | 23.6 | 74.5 | 1.00035 |
| 20.4 | 68.7 | 1.00108 | | 23.7 | 74.7 | 1.00033 |
| 20.5 | 68.9 | 1.00106 | | 23.8 | 74.8 | 1.00030 |
| 20.6 | 69.1 | 1.00104 | | 23.9 | 75.0 | 1.00028 |
| 20.7 | 69.3 | 1.00102 | | 24.0 | 75.2 | 1.00025 |
| 20.8 | 69.4 | 1.00100 | | 24.1 | 75.4 | 1.00023 |
| 20.9 | 69.6 | 1.00097 | | 24.2 | 75.6 | 1.00020 |
| 21.0 | 69.8 | 1.00095 | | 24.3 | 75.7 | 1.00018 |
| 21.1 | 70.0 | 1.00093 | | 24.4 | 75.9 | 1.00015 |
| 21.2 | 70.2 | 1.00091 | | 24.5 | 76.1 | 1.00013 |
| 21.3 | 70.3 | 1.00089 | | 24.6 | 76.3 | 1.00010 |
| 21.4 | 70.5 | 1.00086 | | 24.7 | 76.5 | 1.00007 |
| 21.5 | 70.7 | 1.00084 | | 24.8 | 76.6 | 1.00005 |
| 21.6 | 70.9 | 1.00082 | | 24.9 | 76.8 | 1.00002 |
| 21.7 | 71.1 | 1.00080 | | 25.0 | 77.0 | 1.00000 |
| 21.8 | 71.2 | 1.00077 | | 25.1 | 77.2 | 0.99997 |
| 21.9 | 71.4 | 1.00075 | | 25.2 | 77.4 | 0.99995 |
| 22.0 | 71.6 | 1.00073 | | 25.3 | 77.5 | 0.99992 |
| 22.1 | 71.8 | 1.00030 | | 25.4 | 77.7 | 0.99989 |
| 22.2 | 72.0 | 1.00068 | | 25.5 | 77.9 | 0.99987 |
| 22.3 | 72.1 | 1.00066 | | 25.6 | 78.1 | 0.99984 |
| 22.4 | 72.3 | 1.00064 | | 25.7 | 78.3 | 0.99981 |
| 22.5 | 72.5 | 1.00061 | | 25.8 | 78.4 | 0.99979 |
| 22.6 | 72.7 | 1.00059 | | 25.9 | 78.6 | 0.99976 |
| 22.7 | 72.9 | 1.00057 | | 26.0 | 78.8 | 0.99973 |
| 22.8 | 73.0 | 1.00054 | | 26.1 | 79.0 | 0.99971 |
| 22.9 | 73.2 | 1.00052 | | 26.2 | 79.2 | 0.99968 |
| 23.0 | 73.4 | 1.00050 | | 26.3 | 79.3 | 0.99965 |
| 23.1 | 73.6 | 1.00047 | | 26.4 | 79.5 | 0.99963 |
| 23.2 | 73.8 | 1.00045 | | 26.5 | 79.7 | 0.99960 |

## Theoretical Maximum Density

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To calculate the theoretical maximum density at 25°C (77°F) use one of the following formulas. The density of water at 25°C (77°F) = 997.1 in Metric units or 62.245 in English units.

Theoretical maximum density $kg/m^3 = G_{mm}$ X 997.1 $kg/ m^3$

2.468 X 997.1 $kg/ m^3$ = 2461 $kg/ m^3$

or

Theoretical maximum density $lb/ft^3 = G_{mm}$ X 62.245 $lb/ft^3$

2.468 X 62.245 $lb/ft^3$ = 153.6 $lb/ft^3$

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## Report

Results shall be reported on standard forms approved for use by the agency. Report $G_{mm}$ to three decimal places. Report the theoretical maximum density to agency standard.

## Tips!

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- Use a calibrated flask with known mass when filled, if using flask procedure.
- Check for absorption in uncoated aggregate.

## REVIEW QUESTIONS

1. A mix with the largest aggregate size of 25 mm (1in) should use what size sample?

2. At what temperature should the sample be for testing?

3. Removing the entrapped air from the contents of the flask by a partial vacuum is done for how long?

4. How and why is the flask agitated?

## PERFORMANCE EXAM CHECKLIST

## THEORETICAL MAXIMUM SPECIFIC GRAVITY AND DENSITY OF HOT MIX ASPHALT PAVING MIXTURES
## FOP FOR AASHTO T 209

Participant Name _____ Exam Date _____

**Record the symbols "P" for passing or "F" for failing on each step of the checklist**.

| **Procedure Element** | **Trial 1** | **Trial 2** |
|---|---|---|
| 1. Sample reduced to correct size? | _____ | _____ |
| 2. Particles carefully separated insuring that aggregate is not fractured? | _____ | _____ |
| 3. After separation, fine aggregate particles not larger than 6.4 mm (1/4in)? | _____ | _____ |
| 4. Sample at room temperature? | _____ | _____ |
| 5. Mass of bowl or flask & cover determined to 0.1 g? | _____ | _____ |
| 6. Mass of sample and bowl or flask & cover determined to 0.1 g? | _____ | _____ |
| 7. Mass of sample calculated and conforms to required size? | _____ | _____ |
| 8. Water at approximately 25°C (77°F) added to cover sample? | _____ | _____ |
| 9. Entrapped air removed using partial vacuum for 15 ±2 min? | _____ | _____ |
| 10. Container and contents agitated continuously by mechanical device or manually by vigorous shaking at intervals of about 2 minutes? | _____ | _____ |
| 11. Bowl determination: | | |
| a. Bowl and contents suspended in water at 25 ±1°C (77 ±1.8°F) for 10 ±1 minutes? | _____ | _____ |
| b. Submerged weight of bowl and contents determined to 0.1 g? | _____ | _____ |
| c. Submerged weight of empty bowl determined to 0.1 g? | _____ | _____ |
| d. Net submerged weight of contents calculated? | _____ | _____ |
| 12. Flask determination: | | |
| a. Flask filled with water? | _____ | _____ |
| b. Flask then placed in constant temperature water bath (optional)? | _____ | _____ |
| c. Contents at 25 ±1°C (77 ±1.8°F) or temperature taken and Table 2 in FOP used? | _____ | _____ |
| d. Mass of filled flask determined to 0.1 g, 10 ±1 minutes after removal of entrapped air completed? | _____ | _____ |

**OVER**

| **Procedure Element** | **Trial 1** | **Trial 2** |
|---|---|---|
| e. Mass of flask and water obtained from the Calibration of Flask procedure? | _____ | _____ |
| 13. $G_{mm}$ calculated correctly and to 0.001? | _____ | _____ |
| 14. Density calculated correctly and to 1 kg/m$^3$ (0.1 lb/ft$^3$)? | _____ | _____ |

Comments: First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

Examiner Signature _____WAQTC #:_____